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DNA/PLACES Barium Event Jan: Quick-Look Field Report of "In Situ" Probe Measurements

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NAVAL RESEARCH LABORATORY
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On 12 December 1980, a 48 kg barium payload was launched from the A-15 site of the Eglin/Santa Rosa Island Test Range. The barium was released in the F_1-region of the ionosphere at an altitude of 182.7 km. Approximately 32 minutes later a second rocket was launched, carrying a plasma diagnostics complement which included a pair of pulsed-plasma-probes and an ion mass spectrometer for direct measurements of electron density N_e, temperature T_e, density fluctuations δN_e, associated density fluctuation power spectra $P_n(k)$, and ion composition M_i. The barium release and all associated measurements have been designated by code name JAN.

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20. Abstract (Continued)

cont' This report presents quick-look field analyses of the pulsed-plasma-probe data. A brief description is given on the probe instrumentation, vehicle/payload performance, and "in situ" observations of barium cloud plasma densities and structure.

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DNA/PLACES BARIUM EVENT JAN: QUICK-LOOK FIELD REPORT OF "IN SITU" PROBE MEASUREMENTS

I. INTRODUCTION

At 2311:00 (GMT) on 12 December 1980, a 48 kg barium payload was launched from the A-15 site of Eglin/Santa Rosa Island Test Range. The barium was released in the F_1-region of the ionosphere at 2313:42.1 and at an altitude of 182.7 km.

At 2342:50.8 a second rocket was launched, carrying a plasma diagnostic complement which included a pair of pulsed-plasma-probes and an ion mass spectrometer for direct measurements of electron density N_e, temperature T_e, density fluctuation δN_e, associated density fluctuation power spectra $P_n(k)$, and ion composition M_i. The probe payload penetrated the highest density region (i.e., the highest density observed along the payload's trajectory) of the barium ion cloud at 2344:40.8, a time defined as R+31 MIN. The barium release and all associated measurements have been designated by code name JAN.

This report presents quick-look field analyses of the pulsed-plasma-probe data. A brief description will be given on the probe instrumentation, vehicle/payload performance, and "in situ" observations of plasma densities and structure in the ambient ionosphere and throughout the intense barium ion cloud structure.

II. PROBE INSTRUMENTATION, PAYLOAD CONFIGURATION AND OVERALL SYSTEM PERFORMANCE

A pair of pulsed-plasma-probes were diametrically deployed from the forward-most lateral surface of the payload.

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The payload's ACS was designed to maintain the vehicle axis parallel to the geomagnetic field throughout flight...a condition which optimized data integrity from points of view focused on magnetic-field and vehicle aspect perturbations. Initial results indicate that the ACS functioned according to design. Table 1 lists timer functions and altitudes related to the plasma instrumentation on the probe payload while Figure 1 presents the payload trajectory (alt vs time) as determined by a single station radar solution. The Figure was constructed from the trajectory data listed in Table 2.

The pulsed-plasma-probe[1-4] is a specially designed Langmuir technique which eliminates distortions of the measurement procedure known to degrade the conventional approach to Langmuir probe measurements. In addition, the pulsed probe technique makes possible the determination of absolute electron density under fluctuating plasma conditions and simultaneously determines the electron density N_e, temperature T_e, density fluctuations δN_e, associated power spectra $P_n(k)$ and mean ion mass $\langle M_i \rangle$. The probe's highest resolution capability in event JAN involved δN_e, with resolution down to scale sizes equal to 0.5 meters at a 1km/sec payload velocity.

III. ELECTRON DENSITY PROFILES

The relative electron density profile observed "in situ" by the pulsed probe measurement of baseline electron current I_B^e (See e.g., Ref. 1 or 2) is presented in Figure 2.

The abscissa is expressed as seconds-after-launch, extending over the domain $t_o+75 \leq t$ [sec] $\leq t_o + 373$; while the ordinate is log (I_B^e). The barium ion cloud was encountered on the upleg portion of the trajectory at $t \approx 99.5$ sec (ALT $\approx$ 145 Km). Peak densities within the cloud were observed at $t \approx$ 110 sec (ALT $\approx$ 155 Km). For $t > 135$ sec the probe continued relative density measurements within the undisturbed background ionosphere to an apogee of 241 Km ($t = 245$ sec). (That I_B^e is a reasonable representation of relative electron density without major distortions from aspect sensitivities and/or vehicle potential effects has been verified by a simultaneous measurement of baseline ion saturation currents I_B^i shown in Figure 3. For discussions relative to this point see References 4 and 5.)

To establish initial estimates of absolute electron densities, I-V characteristics generated by the pulsed sweep currents (See e.g., Ref. 3) were hand analyzed at three positions within the cloud. The results indicated a simple I_B^e to N_e conversion according to

$$N_e(\text{cm}^{-3}) = 5.62\ (10^{10})\ I_B^e\ (\text{amps})$$

with an estimated accuracy of $\pm$ 32%. More exact analyses will result in absolute density determinations with a better than 10% accuracy. This conversion has been applied to Figure 2, resulting in initial estimates of peak barium ion densities ($t \approx$ 110 sec, ALT = 155 Km) of $7.3(10^6)\text{cm}^{-3}$. This value represents an enhancement of 300 over ambient

ionospheric conditions at that altitude. An expanded view of the ion cloud domain ($95 < t$ (sec) ≤ 135) is shown in Figure 4 while Table 3 lists densities, altitudes and coordinates of specific observations relevant to a first-order view of the ion cloud and the background ionosphere.

Table 1 — Timer Events Related to the Plasma Instrumentation on the Probe Payload

TIME		EVENT	ALTITUDE (Nom.)
t_o = 2342:50.8		Launch	0
t_o + 66	a)	Nose Cone Separation	90 Km
	b)	Probe Door Deploy	
t_o+ 76	a)	Payload Separation	105 Km
	b)	ACS ON	
	c)	Mass Spec RF ON	
t_o + 78		Yo-Yo Despin	110 Km
t_o + 80		Probe Deploy	112 Km
t_o + 93		Mass Spec HV ON	120 Km
t_o + 108		ACS de-activate	152 Km
t_o + 166		ACS Re-activate	213 Km

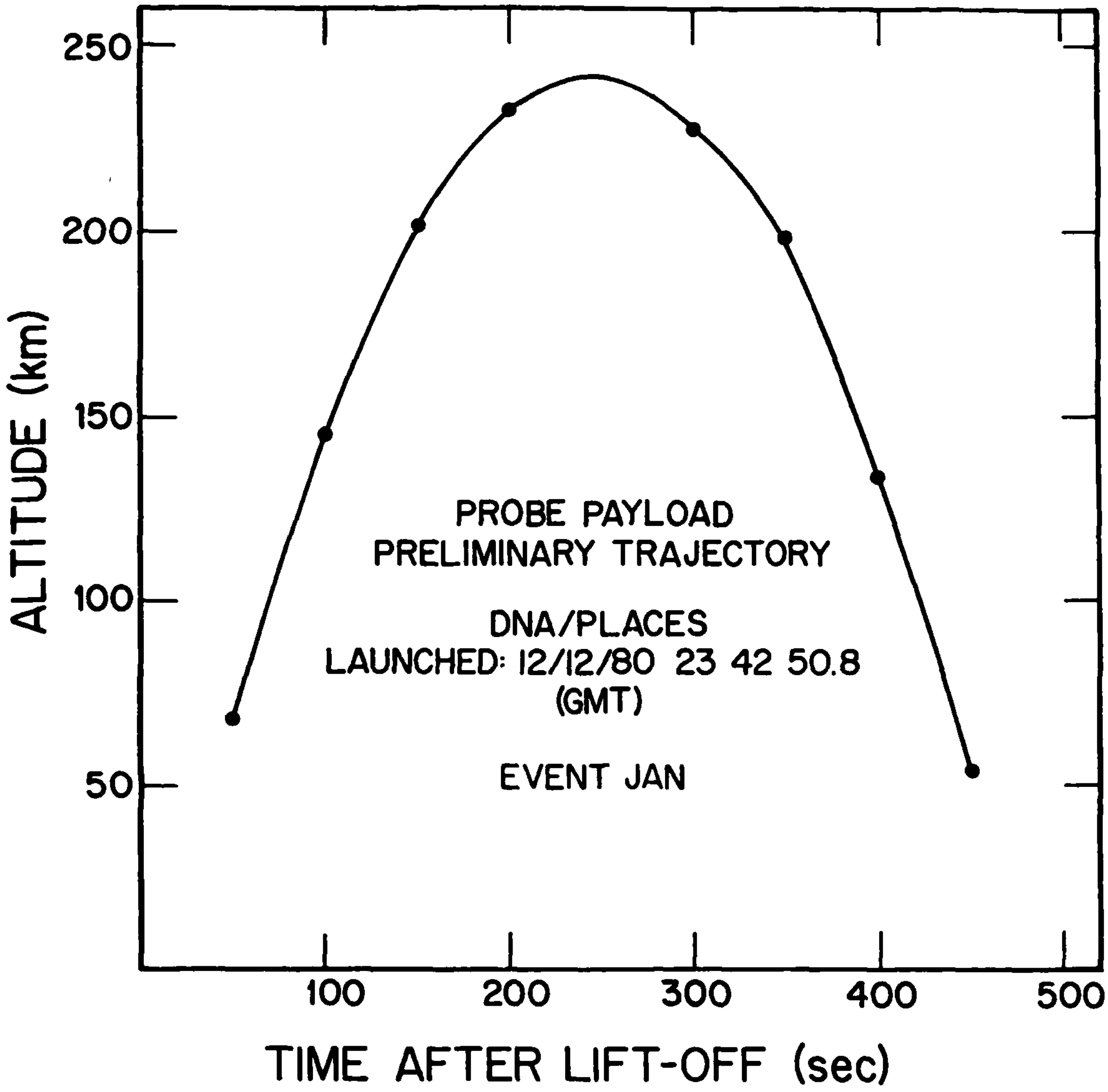

Fig. 1 - Probe payload trajectory from single radar station solution (See Table 2)

Table 2 — Event JAN Probe Payload Trajectory Information Excerpted from a Single Station Radar Solution Prior to Smoothing

TIME AFTER LIFT-OFF	GMT	ALTITUDE		RANGE		LAT	LONG	VEL	
(SEC)		Ft.	KM	Ft.	Km			Ft/Sec	Km/Sec
50	2343:40.8	225,862	68.83	251,479	76.64	30.0855	86.8274	6721	2.05
100	2344:30.8	479,240	146.05	549,004	167.31	29.6615	86.8717	5401	1.65
150	2345:20.8	658,330	200.63	783,270	238.71	29.2428	86.9211	4245	1.29
200	2346:10.8	761,631	232.11	956,354	291.46	28.8321	86.9735	3407	1.04
245.3	2346:56.1	791,530	241.22	1,067,348	325.28	28.464	87.0227	3100	0.94
250	2347:0.8	791,208	241.13	1,076,545	328.09	28.4265	87.0277	3100	0.94
300	2347:50.8	747,856	227.91	1,115,627	352.19	28.0193	87.0830	3452	1.05
350	2348:40.8	650,406	198.22	1,209,267	368.53	27.6732	87.3808		
400	2349:30.8	437,197	133.24	1,260,127	384.03	27.1886	87.1935	5505	1.68
448	2350:18.7	178,136	54.29	1,336,673	407.36	26.7800	87.2469	7577	2.31

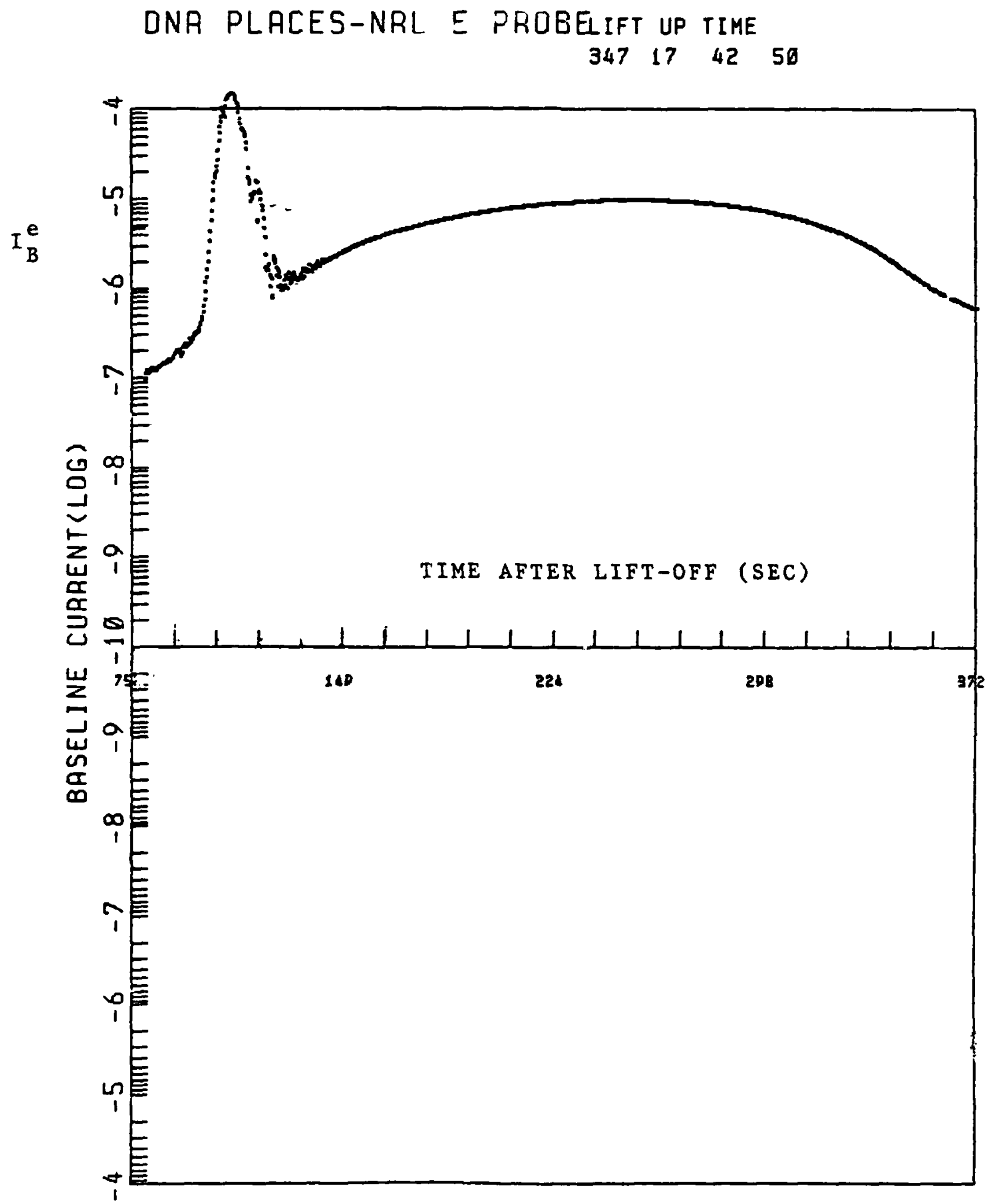

Fig 2 - Relative electron density profile as measured by baseline electron current I_B^e as a function of seconds after launch. Absolute electron densities can be estimated from the conversion N_e [cm^{-3}] = $5.62(10^{10})$ I_B^e [amps]. See text for statement of accuracy.

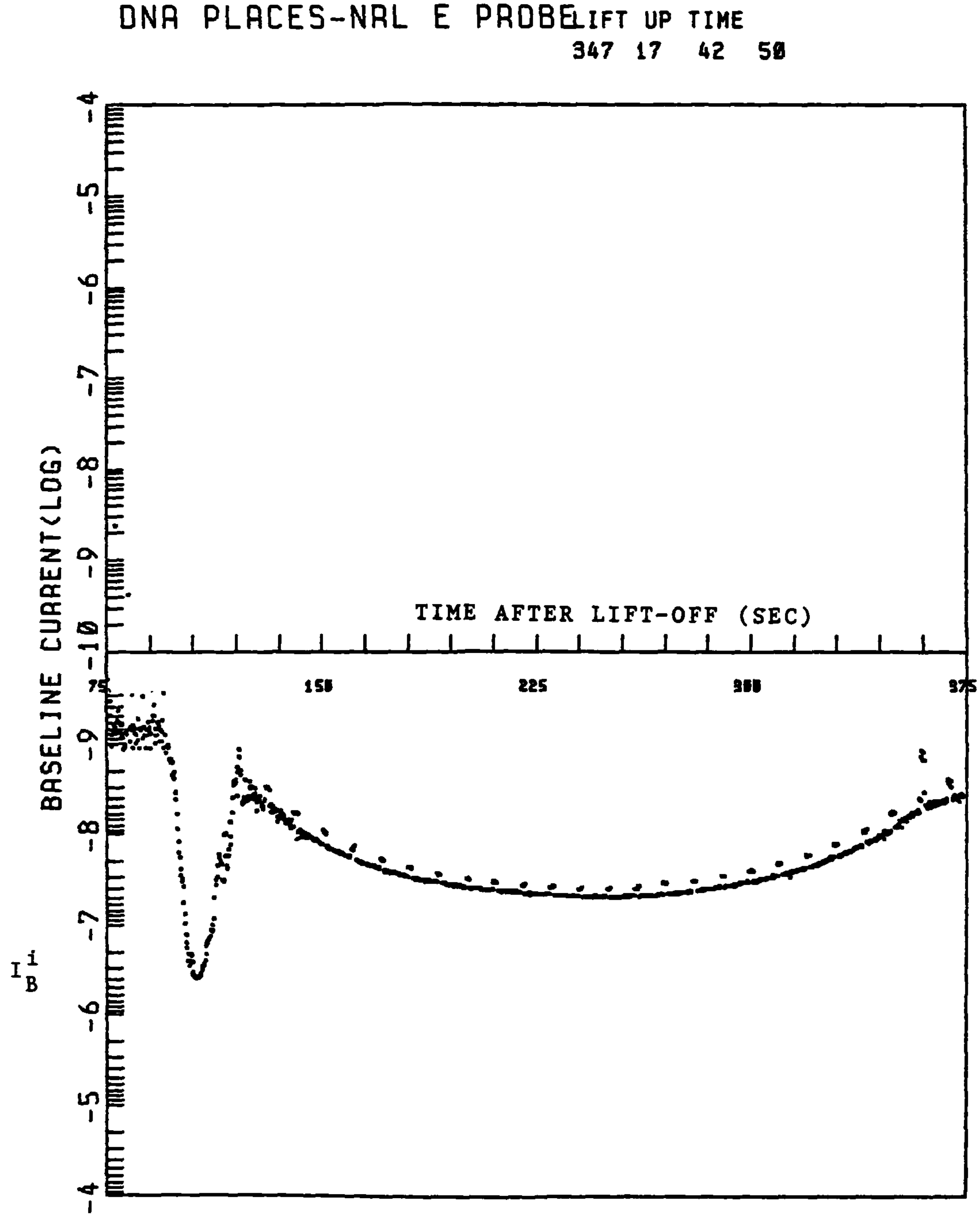

Fig. 3 - Relative electron density profile as measured by baseline ion current I_B^i as a function of seconds after launch. Note that ion current increases downward. Agreement between Figures 2 and 3 establishes credibility in the I_B^e measurements as a reasonable representation of relative density (See text).

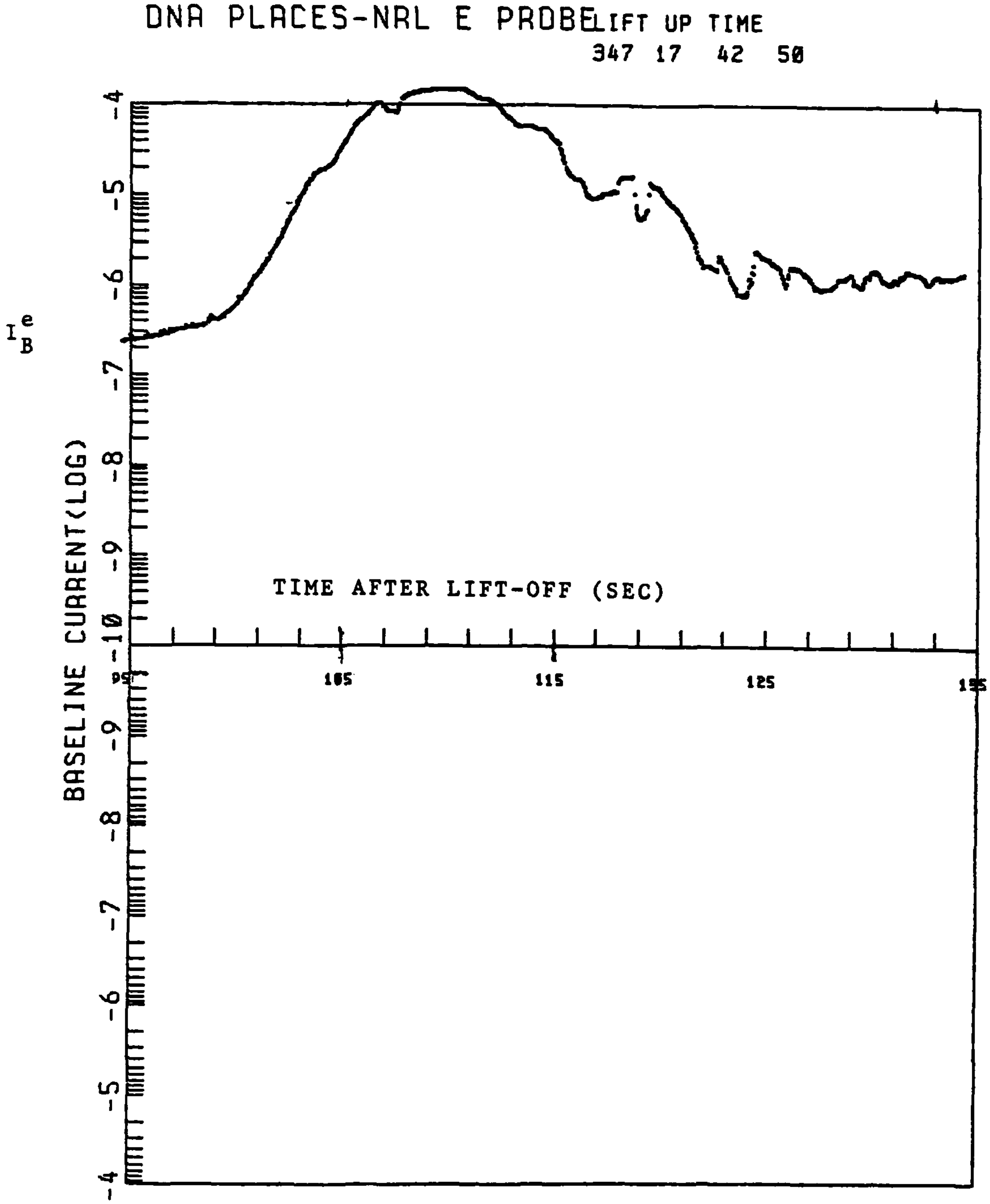

Fig 4 - An expanded view of the barium ion cloud density profile as measured by baseline electron currents. Absolute electron densities can be estimated within an accuracy of $\pm$ 32% (detailed analyses will yield $\pm$ 10% or better) by the conversion N_e [cm^{-3}] = 5.62 (10^{10}) I_B^e [amps].

Table 3 — Summary of Relevant Plasma Densities and Coordinates

POINT OF INTEREST	SEC AFTER LAUNCH	ELECTRON DENSITY IONOSPHERE	ELECTRON DENSITY BARIUM	ALT KM	LAT	LONG
Cloud Entry	99.5	$1.7(10^4)$	@ 10^3	145	29.67^o	86.87^o
Cloud Peak	110	$2.4(10^4)$	$7.3(10^6)$	155	29.58^o	86.88^o
Cloud Exit	135	$5.6(10^4)$	@ 10^2	185	29.41^o	86.9^o
Apogee	245	$5.6(10^5)$	0	241	28.468	87.022

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